DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE

APR 2001

MEMORANDUM FOR: SAF/PAS
1690 Air Force Pentagon - 5D227
Washington DC 20330-1690

FROM: TO:
Francis G. Hinnant, Col, USAF
Associate Director of Acquisition
NPOESS Integrated Program Office
8455 Colesville Rd, Suite 1450
Silver Spring, MD 20910

SUBJECT: Visible/Infrared Imager Radiometer Suite (VIIRS) Foldout Poster

Enclosed are the required ten (10) copies of the subject foldout poster and accompanying technical charts. The Integrated Program Office would like to have this poster and charts available on the public pages of the National Polar-Orbiting Operational Environmental Satellite System website and use the technical information in discussions during several international scientific conferences held in May and June. Your review is requested by 30 Apr 01.

The program office has reviewed the information and found it appropriate for public disclosure without change.

attn:

Point of contact on this matter is Maj Elisa Kang, NPOESS IPO/ADA at 301-427-2084 (Ext. 142).

cc: ADA (E. Kang)

Attachment: Presentation—10 copies

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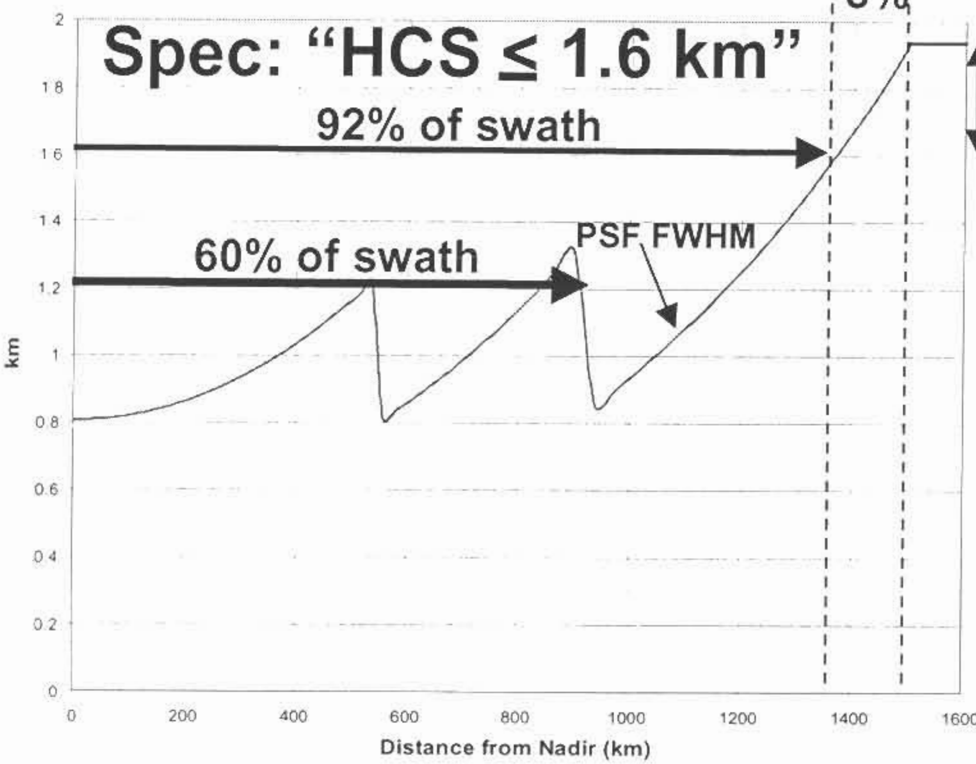
Raytheon

Raytheon Perspectives on Aerospace "Sampling = Resolution" Cha

Contractor has chosen to quote Horizontal Sampling Interval (HSI) as Horizontal Size (HCS), even though they are not numerically equal across the swath.

Since the resulting MTF error does not violate the data quality (APU) requiremen such a definition is permitted, even though it violates accepted practice that F..., not sampling, is the measure of resolution.



In-scan LSF FWHM < 1.2 HCS at EOS (< 1.1 average in 8% edge strip)

Non-issue for 20 EDRs

- Full-swath In-track LSF FWHM < HCS
- Scan resolution = HSI for 60% swath
- Scan resolution (LSF FWHM) < HCS over central 92% of swath
- < 10% average HCS exceedance in 8% of swath near EOS; for 8 EDRs

01-5-2564

3 Cat IIA EDRs at Issue: 1.6 km a Fraction of VIIRS SRD HCS Requirement for Each

Aerospace Recommends FWHM DPLSF HCS Revision | **Retain Current "Boxcar" HCS**

EDRs defined at points and retrieved as local averages		**EDRs not defined at points (e.g., on areas)**
Imagery*	Vegetation Index***	Suspended Matter**
Sea Surface Temperature***	Ocean Currents** **Cat IIIB**	Cloud Cover/Layers ***
Soil Moisture** **Cat IIIB**	Ice Surface Temperature ***	Snow Cover**
Aerosol Optical Thickness**	Net Heat Flux ***	Surface Type ***
Aerosol Particle Size**	Ocean Color/Chlorophyll ***	Fresh Water Ice ***
Cloud EDRs (except Cloud Cover/Layers) ***	Mass Loading ***	Littoral Sediment Transport ***
Albedo**	Precipitable Water ***	Sea Ice Age/Edge Motion***
Land Surface Temperature***		Active Fires** **Cat IIB**

* Resolution specified at instrument level in terms of radiance MTF

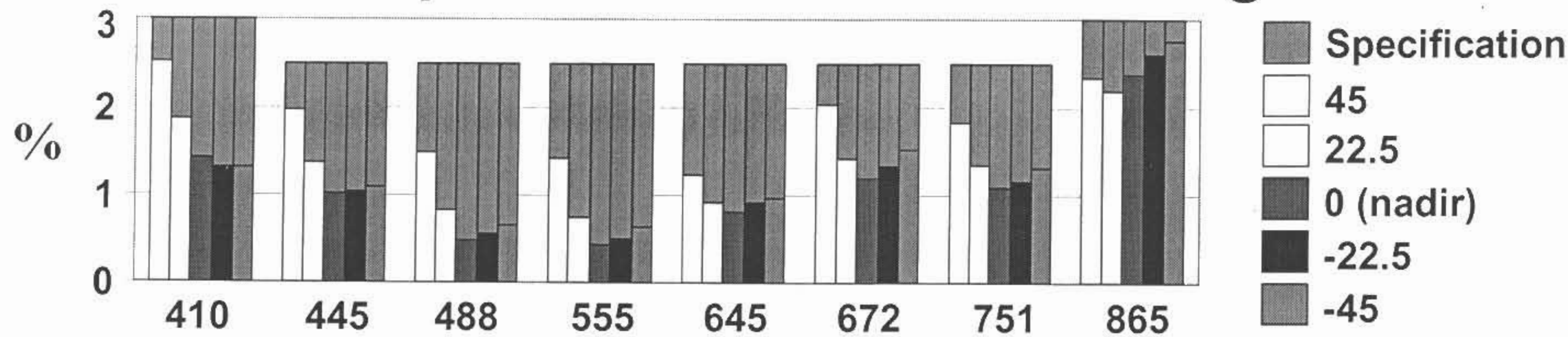
** Worst case HCS specified at 1.6 km over 3000 km swath for data product or sub-product

*** **Worst-case HCS > FWHM sensor LSF for all bands over entire swath in-scan/in-track**

Impact of Striping, Calibration Stability (2)

- Raytheon recognizes the importance of these two topics and the level of effort being expended to address striping in particular for MODIS
- Continued verification of EDR performance as affected by the evolution of the sensor design and EDU fabrication is a nominal Phase II task
- Particular attention will be given to a number of issues, including but not limited to striping and calibration stability
- Raytheon will closely monitor the results obtained by B. Guenther, et al. regarding algorithmic solutions for striping
- The MODIS heritage should provide a basis for the VIIRS algorithmic solution

Tightened Polarization Specification Met with Margin



- Provides 8-83% margin across ± 45 degree scan
- Excellent characterization across entire ± 56 degree scan
  - Amplitude knowledge of 0.5%
  - Phase angle knowledge of 5 degrees
- (SRD requirements are 2% sensitivity or characterization of 0.5% amplitude and 30 degrees phase, across ± 45 degree scan)

Band	Center Wavelength (μm)	Maximum Polarization Sensitivity (%)
M1	0.412	3.0
M2	0.445	2.5
M3	0.488	2.5
M4	0.555	2.5
I1	0.645	2.5
M5	0.672	2.5
M6	0.751	2.5
I2	0.865	3.0
M7	0.865	3.0

Polarization Correction for Ocean Color (2)

- A dual-mirror depolarizer was added at the end of Phase I to improve polarization performance
- This allowed tightening of the polarization specification to 3% or less across all bands related to ocean color retrievals
- In most cases, there is significant margin against this specification (predicted performance of 2% or less), reducing reliance on algorithmic solution
- This issue will be monitored as a normal part of Phase II activities as a Technical Performance Metric (TPM)

		Band No.	Wave-length (µm)	Horiz Sample Interval (km Downtrack x Crosstrack) Nadir	End of Scan	DRIVING EDR(s)	Radi-ance Range	Ltyp or Ttyp	Signal to Noise Ratio (dimensionless) or NEΔT (Kelvins) Nadir	E.O.S.	Required	Margin
VIS/NIR FPA	Silicon PIN Diodes	M 1	0.412	0.742 x 0.259	1.60 x 1.58	Ocean Color	Low	44.9	753	435	352	23.5%
						Aerosols	High	200	1758	1016	841	20.7%
		M 2	0.445	0.742 x 0.259	1.60 x 1.58	Ocean Color	Low	40	975	563	380.1	48.1%
						Aerosols	High	230	2451	1415	886	59.7%
		M 3	0.488	0.742 x 0.259	1.60 x 1.58	Ocean Color	Low	32	1065	615	415.6	48.0%
						Aerosols	High	270	3045	1758	963	82.6%
		M 4	0.555	0.742 x 0.259	1.60 x 1.58	Ocean Color	Low	21	931	538	361.8	48.6%
						Aerosols	High	285	3272	1889	1018	85.6%
		I 1	0.645	0.371 x 0.387	0.80 x 0.789	Imagery EDR	Single	22	326	188	130.7	43.9%
		M 5	0.672	0.742 x 0.259	1.60 x 1.58	Ocean Color	Low	10	637	368	242.1	52.0%
						Aerosols	High	233	3319	1916	1379	38.9%
		M 6	0.752	0.742 x 0.776	1.60 x 1.58	Atmospheric Corr'n	Single	9.6	550	318	199.1	59.5%
		I 2	0.865	0.371 x 0.387	0.80 x 0.789	NDVI	Single	25	435	251	151.2	66.2%
		M 7	0.865	0.742 x 0.259	1.60 x 1.58	Ocean Color	Low	6.4	864	499	215.3	131%
						Aerosols	High	139	3714	2144	1059	102%
	CCD	DNB	0.7	0.742 x 0.742	0.742 x 0.742	Imagery EDR	Var.	6.70E-05	30.0	6.6	6	10.0%
S/MWIR	PV HgCdTe	M 8	1.24	0.742 x 0.776	1.60 x 1.58	Cloud Particle Size	Single	5.4	222	128	101	27.1%
		M 9	1.378	0.742 x 0.776	1.60 x 1.58	Cirrus/Cloud Cover	Single	6	246	142	82.7	71.9%
		I 3	1.61	0.371 x 0.387	0.80 x 0.789	Binary Snow Map	Single	7.3	133	77	6	1178%
		M 10	1.61	0.742 x 0.776	1.60 x 1.58	Snow Fraction	Single	7.3	857	495	342.2	44.5%
		M 11	2.25	0.742 x 0.776	1.60 x 1.58	Clouds	Single	0.12	25.8	14.9	10	49.0%
		I 4	3.74	0.371 x 0.387	0.80 x 0.789	Imagery Clouds	Single	270 K	0.446 K	0.773 K	2.500 K	223%
		M 12	3.70	0.742 x 0.776	1.60 x 1.58	SST	Single	270 K	0.129 K	0.223 K	0.396 K	77.8%
		M 13	4.05	0.742 x 0.259	1.60 x 1.58	SST	Low	300 K	0.024 K	0.042 K	0.107 K	155%
						Fires	High	380 K	0.174 K	0.302 K	0.423 K	40.1%
LWIR	PV HCT	M 14	8.55	0.742 x 0.776	1.60 x 1.58	Cloud Top Properties	Single	270 K	0.027 K	0.046 K	0.091 K	97.5%
		M 15	10.762	0.742 x 0.776	1.60 x 1.58	SST	Single	300 K	0.020 K	0.034 K	0.070 K	105%
		I 5	11.45	0.371 x 0.387	0.80 x 0.789	Cloud Imagery	Single	210 K	0.383 K	0.663 K	1.500 K	126%
		M 16	12.01	0.742 x 0.776	1.60 x 1.58	SST	Single	300 K	0.030 K	0.052 K	0.072 K	39.6%

All Bands Have Comfortable Margin Above EDR-Derived SNR Requirements

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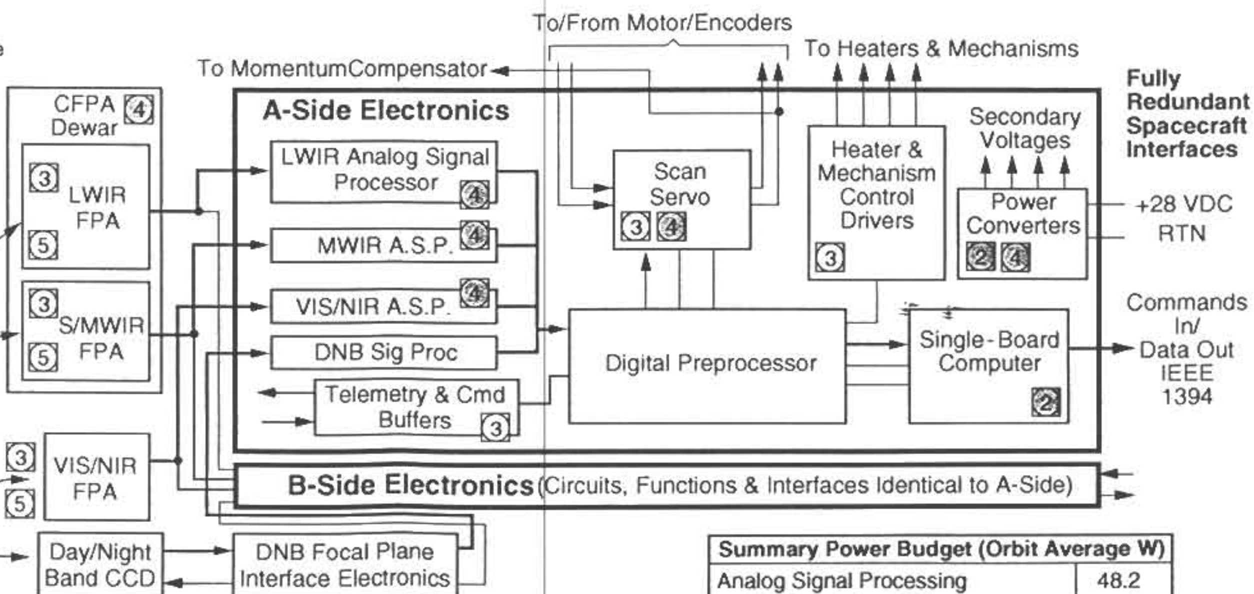

Summary Power Budget (Orbit Average W)	
Analog Signal Processing	48.2
Digital Signal Processing	17.3
Controls, Mechanisms, & Telemetry	24.5
Power Supply & Power Conditioning	44.0
Normal Operational Mode TOTAL	134.0
Peak Power - Calibration Mode	176.9
SRD Not-To-Exceed Value	300.0
Power Margin - Normal Operation	55.3%
Power Margin - Calibration	41.0%

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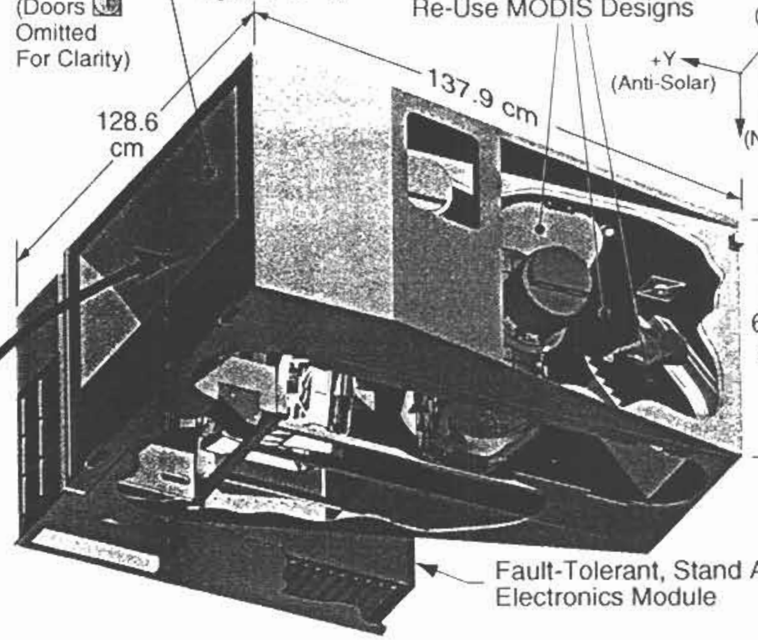
Day/Night CCD Layout & CDR Complete

Day/Night Band-Silicon CCD Detectors	
Dynamic Range	45,000,000:1
Spectral Range	0.5 - 0.9 µm
Ground Sample Interval (Constant Over Scan)	742 km ±5%
SNR @ Quarter Moon Radiance	
Nadir	30:1
End of 3,000 km Scan	6:1

Figure 2-1. VIIRS Sensor Configuration, Accommodation, and Performance Summary

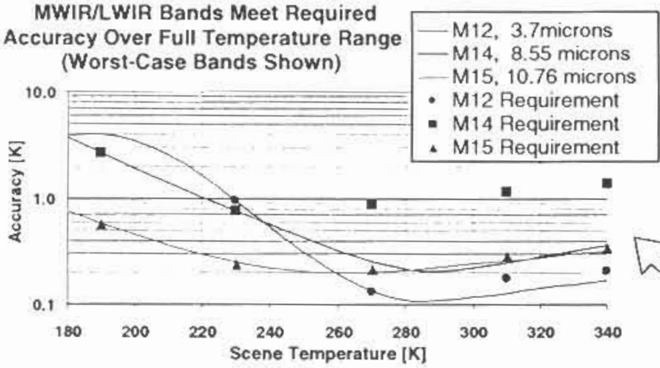
KEY CHARACTERISTICS AND PERFORMANCE
Spectral Bands:
Visible/Near IR: 9 plus Day/Night Pan Band
Mid-Wave IR: 8
Long-Wave IR: 4
Imaging Optics: 19.1 cm Aperture, 114 cm Focal Length
Band-to-Band Registration (All Bands, Entire Scan) >80% Per Axis
Orbit Average Power: 134 Watts (55% Margin)
Weight: 160 kg (20% Margin)
DATA ACQUISITION PARAMETERS:
Scanned Swath: +/-56 Deg, 3,029 km
Downtrack Swath: 11.87 km, 16 to 32 Detectors in Track
Scan Period: 1.786 Sec.
Horizontal Sample Interval On Ground: <1.6 km @ End of Scan
Data Quantization: 12 Bits - 14 Bit A/D Converters for lower noise
Data Rate (Est. Orbit Average - Actual Rate Varies With Scene):
High-Rate Data (2:1 Rice Compression): 6.7 Mbps (16% Margin)
Low-Rate Data (10:1 JPEG Lossy Compr.): 220 Kilobits/Sec.

Raytheon's Modular, Affordable VIIRS Sens
Meets All Requirements and Facilitates Future Improvements



Cryogenic Module: Advanced 3-Stage Radiative Cooler Developed On Raytheon IR&D [3]	
VIIRS Flight Cooler Radiating Area	61 x 91 cm
VIIRS CFPA Operating Temperature	80 Kelvins
Cooler No Load Temperature	64 Kelvins
VIIRS Heat load Radiated to Space - Excluding Control Power, Including Loading By CMIS Antenna & CrIS	296 mW
Heat Load Margin @ 80K & 296 mW Heat Load	51%

MWIR/LWIR Bands Meet Required Accuracy Over Full Temperature Range (Worst-Case Bands Shown)




Solar Diffuser Stability Monitor


Solar Diffuser


Black Body

Reflective Bands Calibration Better Than 2%

Advanced, Sp Focal Plane T

- Highly Linear Phot Extends to 12 µm
- 2nd-Generation Te I.C. Readouts Thr
- Integrated "Microle Lens Arrays Impro
- VIS: PIN Diodes & Sensitivity Day/Nig

Heritage Hardware Reduces Risk

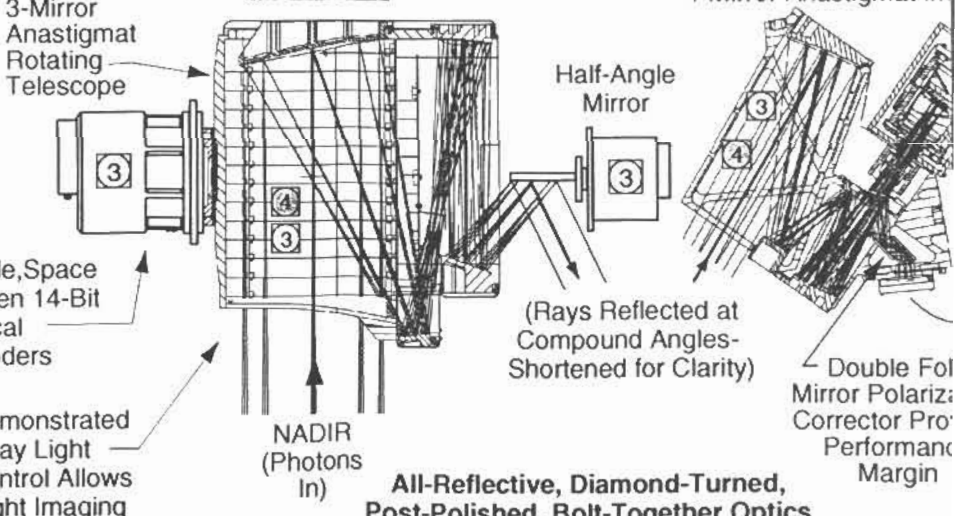
[1] = Space Design Re-Use

[2] = C.O.T.S. Hardware

[3] = Space Design Heritage

[4] = Raytheon-Funded Radiometer Hardware Demonstration

[5] = VIIRS Phase I Risk Reduction Hardware



All-Reflective, Diamond-Turned, Post-Polished, Bolt-Together Optics

Summary Mass Budget (kg)	
Fore & Aft Optics	26.4
Cryoradiator & Dewar	19.4
On-Board Calibrators	9.1
Mechanisms, Doors, Actuators	8.7
Mainframe & Structural Elements	37.8
Electronics Module	49.6
External Cabling & Nadir Panel	9.0
Total	160.0
SRD Not-To-Exceed Value	200.0
Margin	20.0%

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The VIIRS Informational Data Set

The following information on the design, construction, operation, and performance of the VIIRS instrument is submitted for your review and approval for release to the operational and scientific user communities, as well as to the public at large. This large volume of data will be supporting an even larger scientific audience than ever before due to the long-term climate data support that VIIRS will be providing to that community.

The information contained herein is not proprietary or competition sensitive. No manufacturing processes are discussed.

The material is organized at the VIIRS subsystem level. Each subsystem section is hyperlinked to this page. Attached are the VIIRS ATBDs as well as the VIIRS Foldout Information Sheet.

VIIRS Subsystems:

1. Selected Sensor Performance Parameters
2. Mainframe Structure
3. Rotating Telescope
4. Optics
5. Cryoradiator
6. FPA Dewar
7. FPA Layouts
8. Electronics Module
9. Radiometric Performance/Band to Band Registration
10. EDRs

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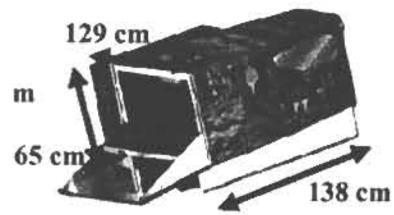
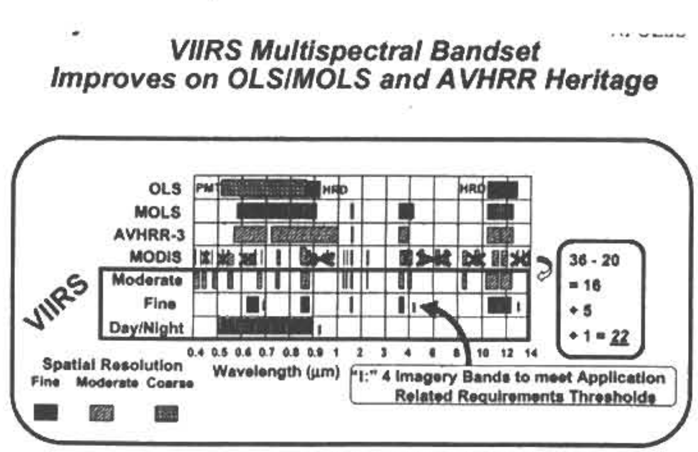
Selected Performance Parameters

Physical Characteristics (Volume, Dimensions, Mass, Power):

VIIRS
<1.2 m^3/160 kg/134 W

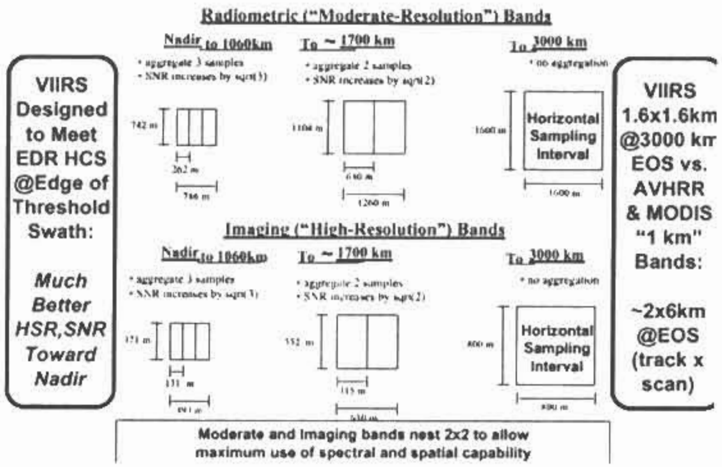


VIIRS Band Set Compared to Current Sensors

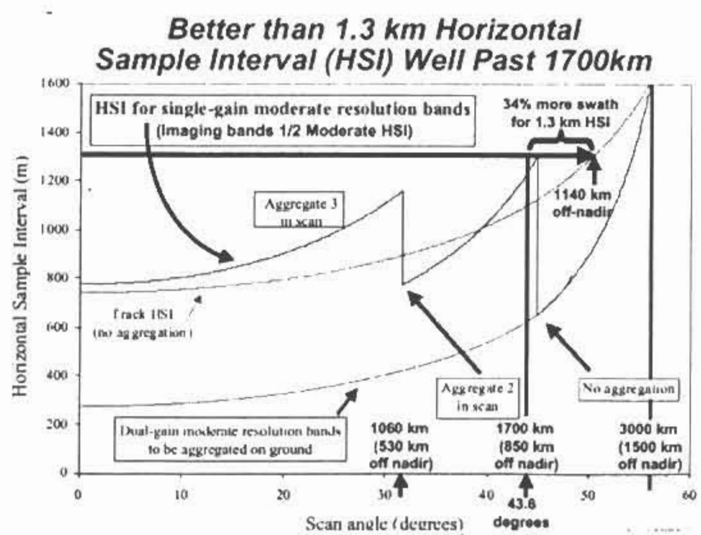


All bands produced from single, inherently co-registered sensor

VIIRS Spatial Resolution for Imagery and Radiometric Bands:



VIIRS Aggregation Approach:

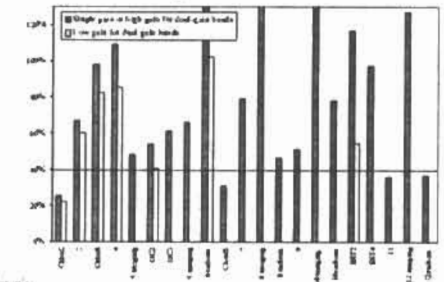


Projected VIIRS Performance Margins:

Margin Available at PDR Assures Low Risk Development

Performance Margin:

- SNR > 40% for majority of bands
- MTF > 10% for majority of bands

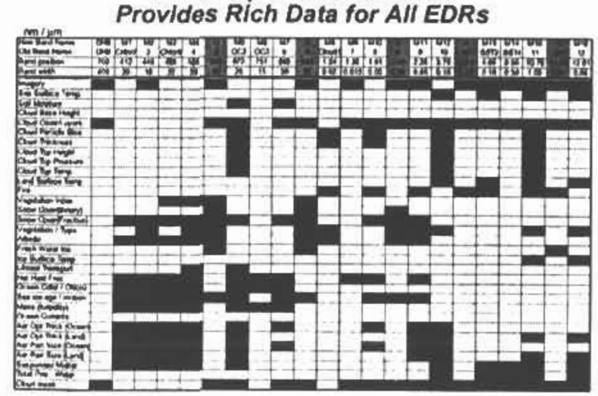


Accommodation Margins:

- Mass - 160 kg predicted, 176 kg specified, SRD NTE is 200 kg; provides 10% growth from predict to specification, 20% to NTE
- Power (operational average) - 134 watts predicted, 170 watts specified, SRD NTE is 300 watts; provides 20% margin from specification, 68% to NTE

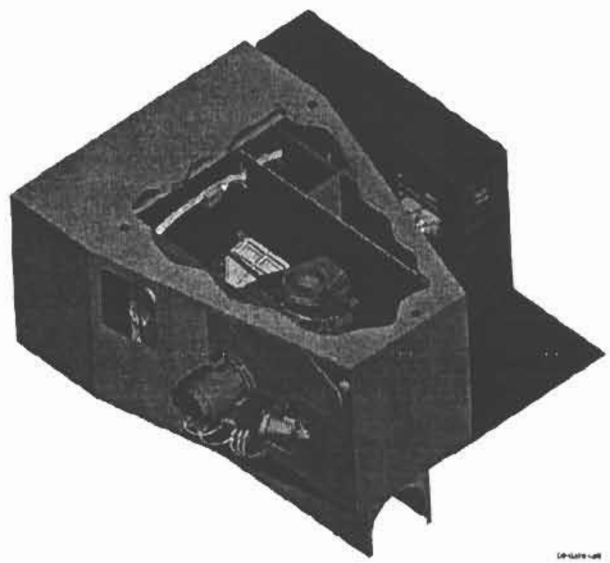
VIIRS Band Set & EDR Utilization:

VIIRS' Optimized Bandset Provides Rich Data for All EDRs



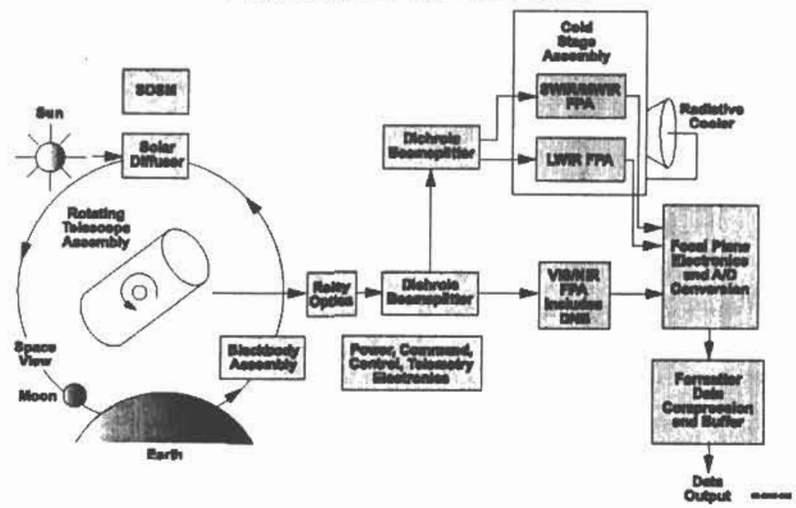
VIIRS Perspective Drawing:

Single Sensor Optimum for VIIRS Suite



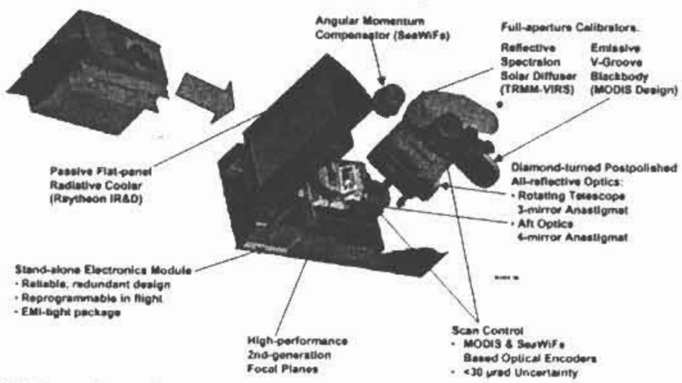
VIIRS Operational Flow Through:

VIIRS Sensor From Photons In To Bits Out



VIIRS Major Subsystems/Components:

Single Sensor VIIRS Improves Data Quality Reduces Integration Costs

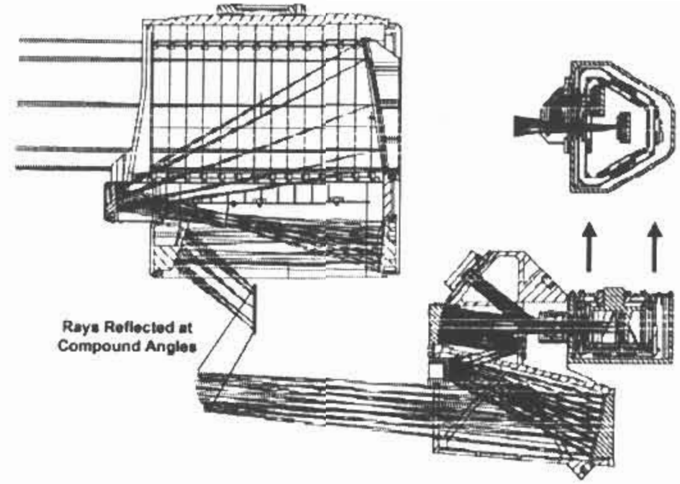


VIIRS Operational Flexibility:

VIIRS Designed For Operational Flexibility

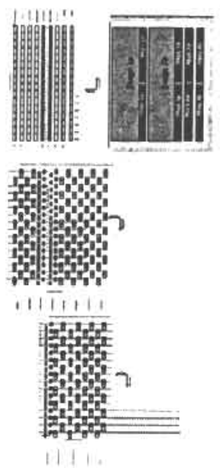
- All functions individually commandable
  - Exceptional versatility for operations & diagnostics
- Macro Commands (stored sequences) simplify commanding & reduce uplink data requirements
  - All macros reprogrammable
- Time tagged commands allow delayed execution
  - Economically provides for 30 day autonomous operation
- Swath widths & locations individually programmable by band
  - Upon command, could provide improved-resolution views of selected targets near nadir
- Diagnostic Mode features improved versatility
  - Telemetry system can "dwell" on any telemetry point to increase sample rate
  - Data processing functions (aggregation, data compression) can be individually enabled & disabled.

VIIRS Optical Train Design:



VIIRS FPA Layout:

All-2nd Generation FPA Technology - Outstanding Performance & Low Risk



- VisNIR PIN diode array/ROIC hybrid colocated with Day/Night Band monolithic CCD
- S/MWIR & LWIR FPAs: Photovoltaic HgCdTe
  - Integrated "Microlens" arrays reduce background noise
- All FPA performance parameters meet Threshold requirements & approach Objectives
- Optical alignment of all FPAs provides optimum band-band registration

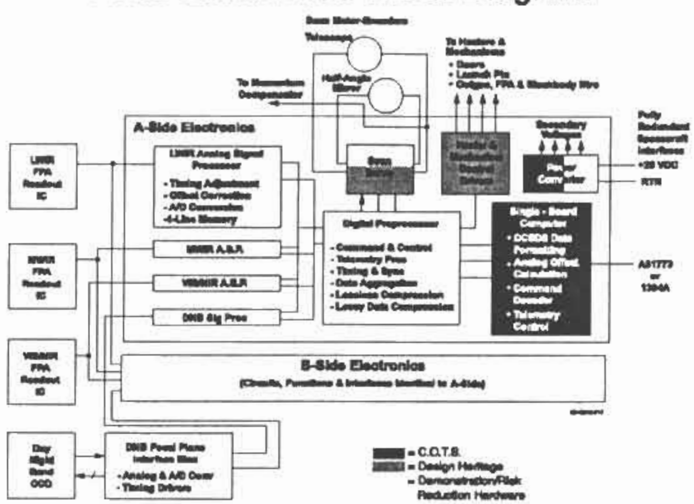
VIIRS Electronics Design Characteristics:

Block-Redundant Electronics Module is Versatile, Reliable & Economical

- Module contains two complete sets of circuits, providing complete single failure tolerance.
- Each Module can perform all electronics functions
  - Command decoding & sensor timing & control via Single Board Computer & FPGA-based Digital Preprocessor
  - Data acquisition from all Focal Plane Assemblies
- Commercial off-the-shelf Processors & Power Supplies
  - Radiation-hard, space proven
- Low-risk electronics packaging approach meets EMI requirements
  - Single box delivered to Integration & test

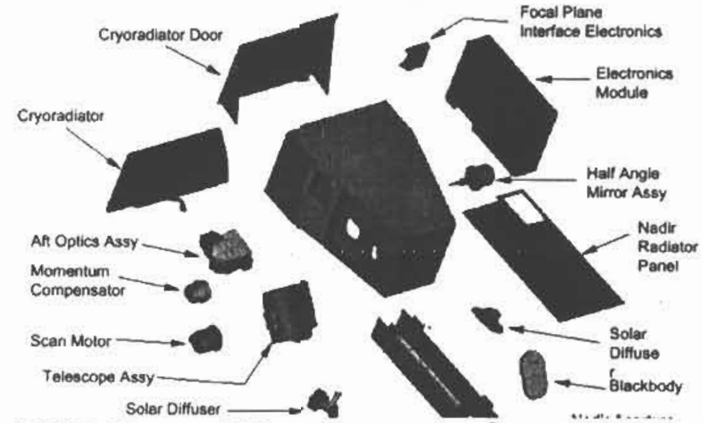
VIIRS Electronics:

VIIRS Electronics Block Diagram



Mainframe Structure

VIIRS Opto-Mech Assemblies Take Advantage of Heritage and Demo Hardware

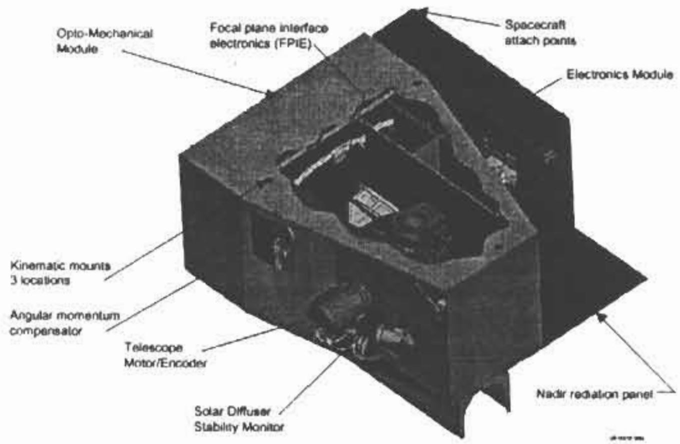


VIIRS Meets All Instrument-to-Spacecraft Requirements With Mass and Power Margin

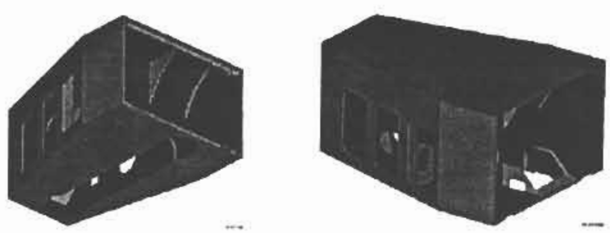
	SRD NTE	VIIRS Allocation	Design Prediction
Envelope (cm)	129 65 138	129 velocity 65 nadir 138 anti-solar	Meets
Mass (kg)	200	176 w/margin	160
Power (W)	300	240 peak* 170 orbit avg.	134 avg.
High Rate Data (Mb/sec)	8.0 10.5	8.0 orbit avg. 10.5 peak	6.7 orbit avg. 8.3 peak
Low Rate Data (kb/sec)	230	230	79

*Operational mode with calibration

Optics Stability Enhanced by Separate Electronics Module



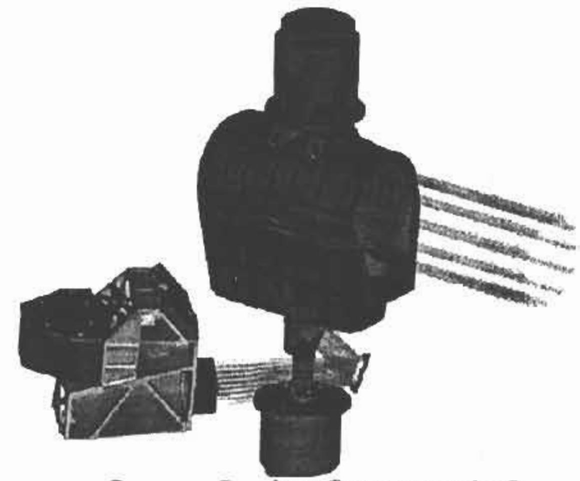
Light-weight Mainframe Meets Weight and Manufacturability Goals



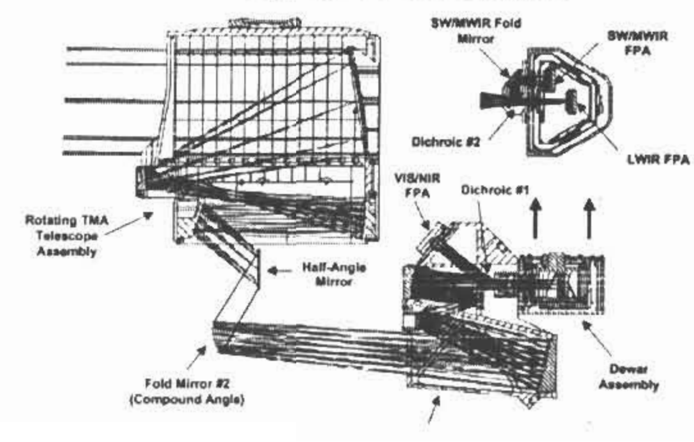
- Combination of bonding and bolting connects bulkheads and skins
- Removable access panels facilitates installation of major assemblies
- High load carrying bulkheads made with honeycomb cores and skins
- Kinematic mount locations selected to maximize stiffness > 50 Hz

Rotating Telescope

Compact, All Reflective Optical Design



Sensor Design Composed of Modular Optical Subassemblies



- Compact Optical Design Satisfies SRD Envelope Requirement
- All Optical Materials and Subassemblies Have Space Qualified Heritage
- Diamond Turned, Bolt Together Telescope and Aft Imager Ensure High Performance, Low Cost Assembly
- Near Telecentric Dewar Design Provides Excellent Spectral Separation, Distributed Out-of-Band Blocking and Background Noise Reduction
- Manufacturing Tolerances Included in CodeV Model
- Generous Margins Exist in Optical Fabrication, Making Assembly and Testing Streamlined

VIIRS All Reflective Approach: A Natural Design Progression

- The MODIS Design is High Performing, but the Aft Optics Alignment was Time Consuming
- DPT Manufacturing Technology at the Time of MODIS Design was Less Mature and Therefore Infeasible for MODIS
- DPT Bolt Together Optics Technology Improvements Now Support an All Reflective Design
  - Permits Reflective Aft Optics FMA Imager (vs. Refractive)
- Elimination of Refractive Elements Reduces Crosstalk, Ghosting, Bulk Scatter, Aberrations and Alignment Cost
- Superior Spectral Transmittance and Image Quality Reduces Number of Focal Planes
- An All Reflective Design is a Natural Progression for a Superior Performance, Lower Cost Instrument

Radiometer Pathfinder Rotating Telescope

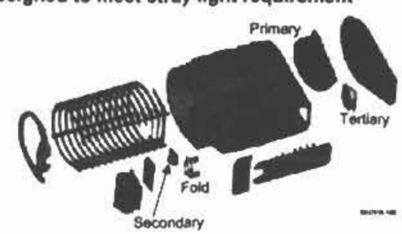
Telescope Housing and Baffle Set

Telescope Mirror Set

Baffle Assembly

Three Mirror Rotating Telescope Housing and Baffles Meet Mass and Inertia Requirements

- Rotating telescope mass (based on aluminum) estimated at 8.5 kg with counterweight
- Rotating mass inertia of .25 kg-m^2
- Diamond point turning/bolt together approach minimizes assembly cost
- Baffles can be assembled then inserted into housing
- Low solar absorptance exterior white paint and black Aeroglaze Z-306 interior designed to meet stray light requirement



Fore Optics Requirements

SPECIFICATION DESCRIPTION	TELESCOPE RQMT. DESCRIPTION	REQUIREMENT VALUE	VERIFICATION METHOD
PS154640-111	PQ vibration X, Y, Z axes	16.8, 9.5, 9.7 grms	T
PS154640-112	PQ temperature range	-41°C to 60°C	T
PS154640-115	Bearing runout	5 arc-sec.	I
PS154640-115	Balance	0.7 kg-mm	I
PS154640-114	Telescope motor/encoder (norm.)	4.4 W pk, 3.4 W avg	T
PS154640-114	Telescope motor/encoder (stow)	3.4 W	T
PS154640-114	Angular Momentum Compensator	2.3 W pk, 1.9 W avg	T

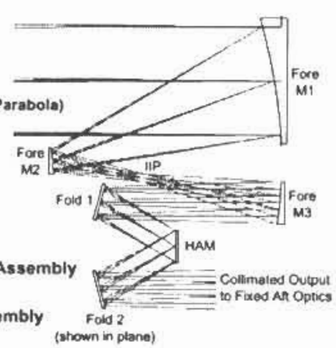
SPECIFICATION DESCRIPTION	HALF ANGLE MIRROR (HAM) RQMT. DESCRIPTION	REQUIREMENT VALUE	VERIFICATION METHOD
PS154640-111	PQ vibration-X axis	17.6, 9.5, 8.8 grms	T
PS154640-112	PQ HAM motor/encoder temp. range	-39°C to 63°C	T
PS154640-115	Bearing runout	5 arc-sec	I
PS154640-115	Balance	0.7 kg-mm	I
PS154640-114	HAM motor/encoder (normal)	2.3 W pk, 1.9 W avg	T

PS154640-115	Fore Optics weight	18.4 kg	T
PS154640-112	Thermal distortion uncertainty	5 arc-sec.	I

PQ = protoqualification

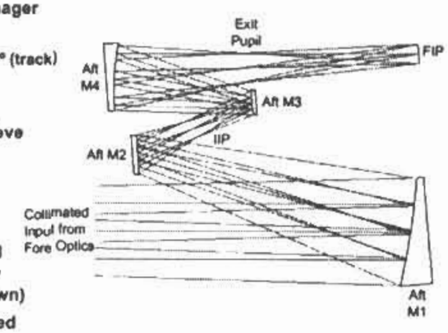
High Performance Fore Optics TMA is Designed for Ease of Manufacture

- Off-Axis, 4X Afocal TMA
  - EPD = 190.5 mm
  - FOV = 1.427° (scan) x 0.815° (track)
  - All Conic Design (Parabola, Hyperbola, Parabola)
    - No General Aspheres
    - Ease of Fabrication, Alignment and Test At Both Component and System Level
  - IIP for Stray Light Rejecting Field Stop
  - Telescope Exit Pupil Located on HAM
- Constant Rate Rotating Telescope
- Fold Mirror #1 Rotates with Telescope Assembly
- Constant Rate, Double-Sided HAM Rotates at 1/2 Speed of Telescope Assembly

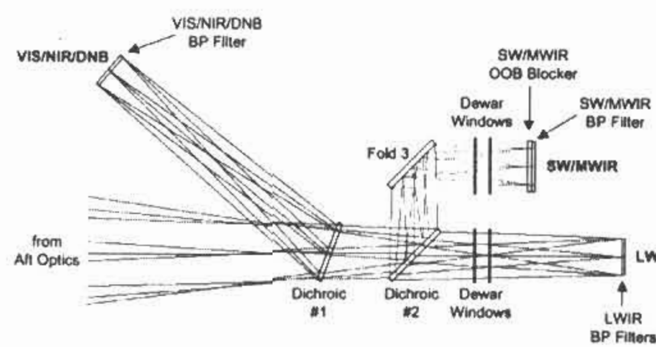


Aft Optics FMA Maintains High Performance Over Expanded FOV

- Compact, All Reflective Imager
  - EPD = 47.625 mm
  - FOV = 5.71° (scan) x 3.26° (track)
  - F/6 System
- Off-Axis FMA Requires General Aspheres to Achieve Imaging Performance
- IIP Allows Distributed Spectral/Spatial Filtering and OOB Blocking
- Accessible, Real Exit Pupil Relayed to IR Detectors by Microlens Arrays (not shown)
- Image Plane AOIs Minimized



Back End Optics Provide Spectral Separation into Three FPA Channels



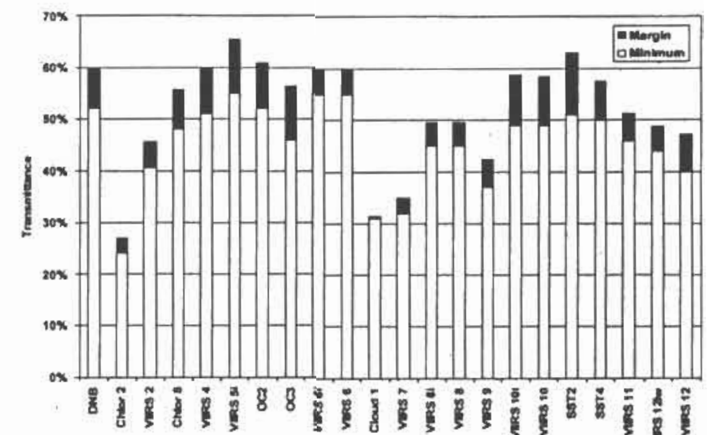
*Optics shown in-plane for clarity. Microlens arrays and detectors not included.

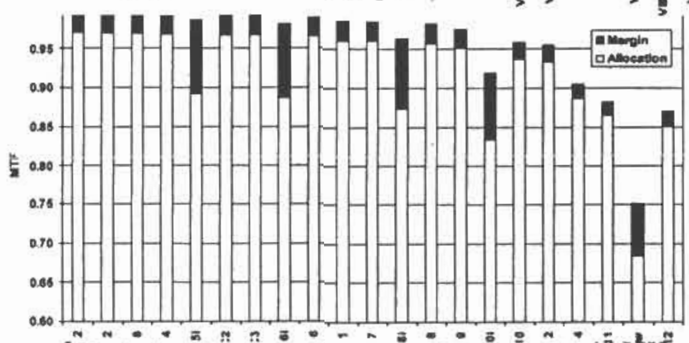
AFT OPTICS REQUIREMENTS

Specification Number	Requirement Description	Requirement Value	Verification Method
PS154640-111	PQ vibration-X axis	13 grms	T
PS154640-111	PQ vibration-Y axis	9.9 grms	T
PS154640-111	PQ vibration-Z axis	10.2 grms	T
PS154640-115	Weight	8.0 kg	T
PS154640-112	PQ temperature range	-40°C to 63 °C	T
PS154640-113	Alignment to boresight and scan plane	0.2 IFOV (at system level)	I

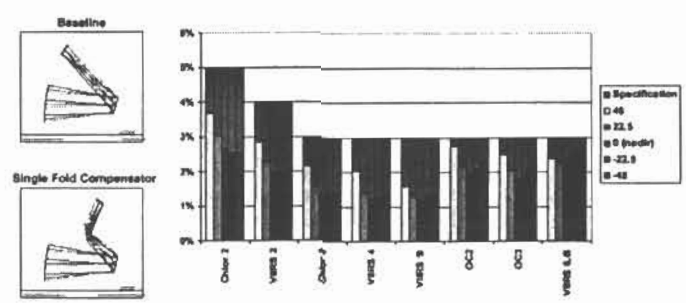
PQ = protoqualification

Dynamic Range Allocation With Margin

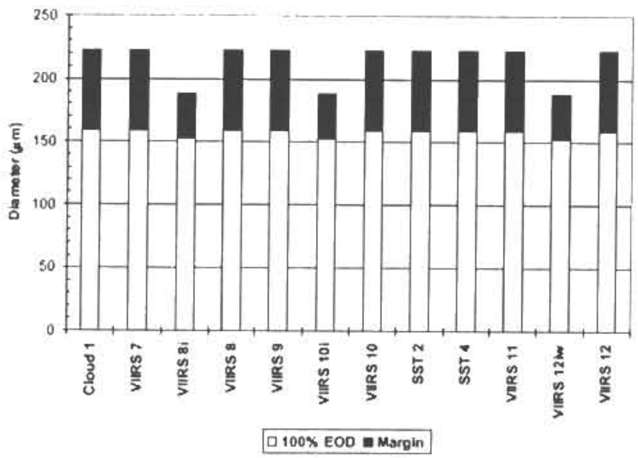




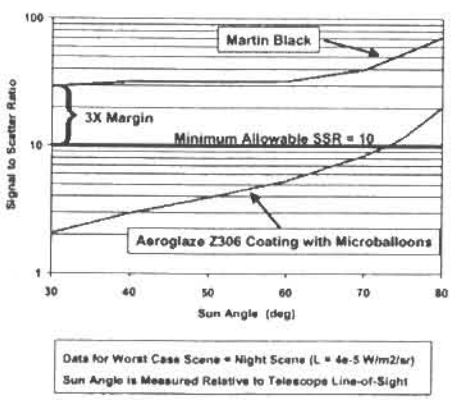
Polarization Requirement Met in All Bands
With Margin Using Single Mirror Compensator



Microlens Arrays Relay Pupil Image with 100% Energy on Detector

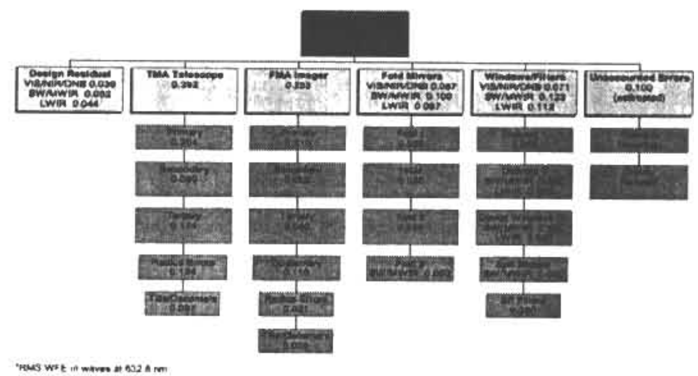


Baffle Design Meets DNB Performance Requirement with Margin



- The Requirement for SSR ≥ 10 is Derived from Low Light Imagery at Scene Radiance Levels of 4E-5 W/m2/sr
- Vanes Require High Efficiency Black Surface (TIS ≤ 1%) to Achieve Required Glare Suppression
- Martin Black Coating Yields SSR > 30

Preliminary Wavefront Error Allocation Is Achievable



Tolerance Analysis Confirms Robust Optical Design

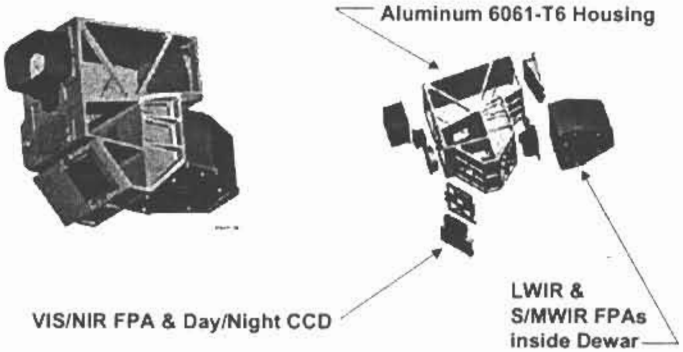
- Current Manufacturing Capabilities of DPT Technology Vendors Validated by Recent Hardware Programs
  - THEMIS, SBIRS Low Tracker, MFS[1], EKV, Radiometer Pathfinder
- Applied Tolerances Provide Margin over Current Vendor Capabilities
  - Radius = 0.05% (0.02%)
  - Tilts (α,β,γ) = 100 µrad (50 µrad)
  - Decenters (x,y,z) = 0.001" (0.0005")
- Preliminary Monte Carlo Tolerance Analysis of VIIRS Optical Design Confirms Ease of Fabrication, Assembly and Alignment
  - MTF Degradation at VIIRS Spatial Frequencies Negligible
  - Toleranced Performance Satisfies Preliminary WFE Budget
- High Performance Optical Design is Robust, Stable and Readily Manufacturable
- Phase II Detailed Tolerancing Study Will Determine Optimal Balance of Tolerances to Further Maximize Producibility and Ensure Cost Effective System

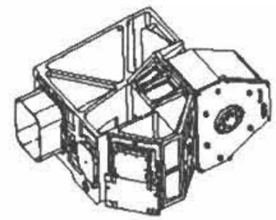
Energy On Detector Insensitive to Microlens Array Tolerances

Tolerance Parameter	Manufacturing Capability	Applied Perturbation	Δ 100% EOD Diameter
Radius	1%	2%	< 0.1 pixel
Index	0.001	0.002	< 0.1 pixel
Thickness	0.001"	0.002"	< 0.1 pixel
Decenter (x,y)	0.0004"	0.001"	< 0.1 pixel
Decenter (z)	0.0007"	0.001"	< 0.1 pixel

- **Vendors Consulted for Current Microlens Array Manufacturing Capabilities**
- **CodeV Model Perturbed with Overly Conservative Values to Ensure Comfortable Margin, Lower Risk and Reduced Cost**
- **Effect of Relaxed Manufacturing and Alignment Tolerances on 100% Energy on Detector (EOD) Diameter Insignificant**
- **100% EOD Maintained Until Image "Walks Off" Detector due to Microlens Array to Detector Array Misalignments**
- **Baseline Detector Sizes Provides Sufficient Margin to Maintain 100% Energy even with Relaxed Perturbations**

FMA Housing Carries Imaging Optics and All Focal Planes

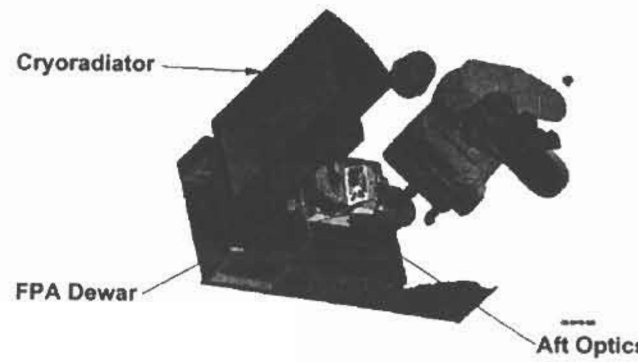




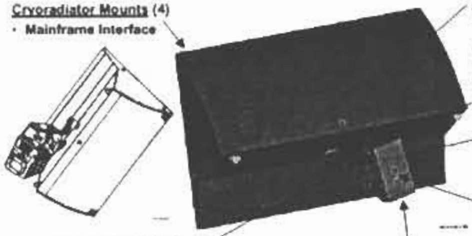
- **VIIRS single 4 mirror imager housing has machined datums for all focal plane assemblies**

Cryoradiator

Cryogenic Module Includes Cryoradiator and FPA Dewar



Cryogenic Module Design Description



Cryogenic Module Meets All Design Requirements

Specification Number	Requirement Description	Requirement Value	Verification Method
PS154640-111	PQ vibration-X axis	9.9 grms	T
PS154640-111	PQ vibration-Y axis	9.6 grms	T
PS154640-111	PQ vibration-Z axis	11 5 grms	T
PS154640-115	Weight	19.4 kg	I
PS154640-112	PQ temperature range	-25°C to 60°C	T
PS154640-112	IR FPA operating temperature	80 K	T
PS154640-112	DNB FPA operating temperature	251±2K	
PS154640-112	Cold stage thermal margin at PDR	45% min (7 K)	A
PS154640-112	Predicted cold stage heat load (dewar/thermal link)	107 mW	A
PS154640-113	Co-registration of focal planes	0.2 IFOV (at system level)	A
PS154640-115	Volume	91 x 61 x 31 cm max	I
PS154640-115	Mission life	15 years (7 years on orbit)	A

PQ = protoqualification

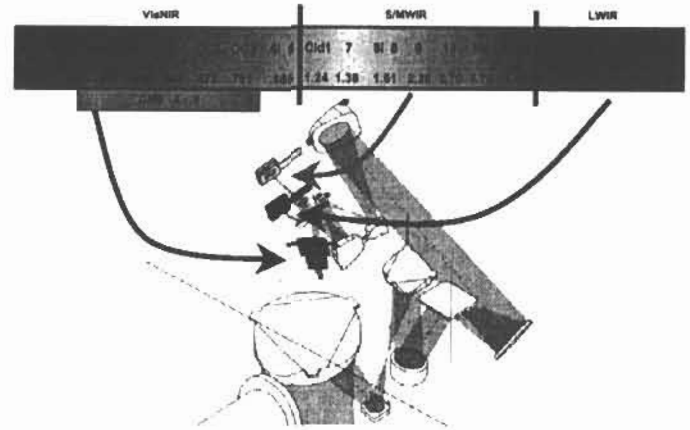
FPA Dewar

Cryogenic Module Has Significant Features and Benefits for VIIRS

- Cryoradiator and dewar assemblies provide high reliability and long life in a low cost, low risk design
- VIIRS cryogenic module derived from flight-proven heritage designs and demonstrated in laboratory hardware

Key Features	Benefits
Passive Cryoradiator • Raytheon PRCs have proven orbit life in excess of 15 years without degradation • Simple aluminum construction • IR&D version built and tested	• Meets VIIRS 15-year life requirement with high reliability and very low risk • Low cost, low schedule risk, meets weight reqm'L • Reduced risk for larger VIIRS configuration
FPA Dewar • Heritage-based design (TM, MODIS) • Multiple stages minimize heat loss • Stage supports are special composite mat'l • Sealed housing permits evacuation • Designed for ease of manufacture	• Low risk • Allows use of cryoradiator • Stable optical alignment • Allows ambient bench testing for SI&T flexibility • Low cost, low schedule risk

Four FPAs Cover Full Spectral Range

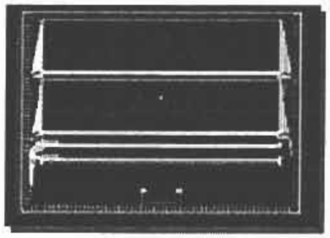


FPA Requirements Driven by System Specification

Parameter Specification #	Units	DNB	VisNIR	S/MWIR	LWIR	Compliance	Verif.
Response Non-linearity	%	±2	<1	<1	<1	Comply	A
Spectral Resp Uniformity	%	4	±15	±15	±15	Comply	T
NEI (most challenging band)	ph/s/cm²	2.50E+07	2.51e9 (Clr9)	3.15e10 (Cld1)	4.33e12 (B11)	Comply w/ ave 30% margin	T
In-Band Irradiance Range	ph/s/cm²	1.5e8 - 1e15	various	various	various	Met with multiple gain stages	T
Band to Band Crosstalk	%	<0.2	<0.2	<0.2	<0.2	Comply, All detectors guarded	T
Intra Band Crosstalk	%	<0.2	<0.2	<0.2	<0.2	Analysis predicts <0.1%	T
Output Signal Swing	V	1.25	2	2	2	Design for 2.35V end of life	T
Output Offset Uniformity	mV	±0.180	<250	<250	<250	Comply	T
Minimum Noise Floor	µV	150	250	250	250	Comply	T
Maximum Power	mW	350	<40	<40 S/M & LW Combined		Comply	T
Operating Temperature	K	253	Ambient	80	80	Comply	T
µlens to Det Alignment tol	µm	n/a	n/a	±25	±25	Comply w/ innovative processes	E

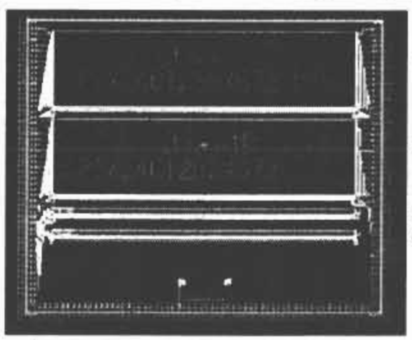
FPA Layouts

Accelerated Day Night Band Development Schedule Has Minimized Risk



- DNB CCD Risk Drivers Have Been Mitigated
  - Phase 2 Schedule Shortened with CCD CDR
  - Radiation Performance has been Quantified
- Phase 2 Schedule
  - PDR conducted 2/16/00
  - TIM Conducted 3/21/00
  - CDR conducted 5/9/00
- Radiation Response Addressed
  - Double Band allows voting
  - Test Data Validates Approach
- Specification and Interfaces Defined

DNB CCD Architecture Supports Large Dynamic Range

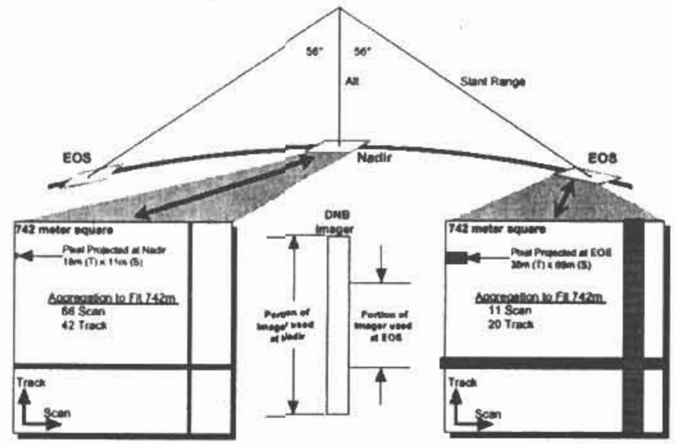


Stage 1a
Stage 1b
Stage 2
Stage 3

CCD Key Characteristics
Pixel Pitches:
-Track: 24.2μm
-Xtrack: 15.4μm
Downtrack Channels: 672
Neutral Density Filter:
-Stage #3: 35:1 reduction
Array Noise Floor:
-Stage #1a & 1b. 10 e- rms
-Stage #2: 17 e- rms
-Stage #3: 74 e- rms
Operating Temperature: 253K

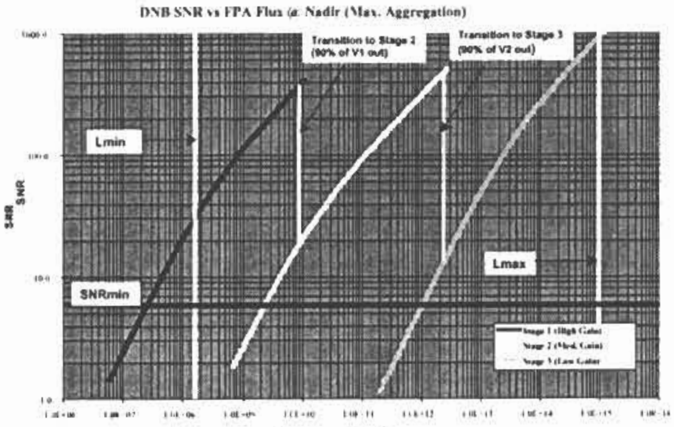
Multiple Stages of Detector Registers are used to Manage Dynamic Range and to Provide Redundancy for SAA Transient Effects

On-Chip Variable Aggregation Provides Constant Horizontal Reporting Interval Throughout Scan

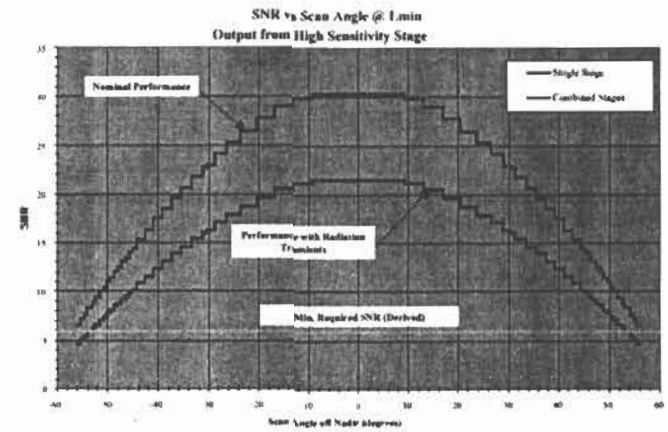


Aggregation Implemented in CCD to Reduce Data Rate

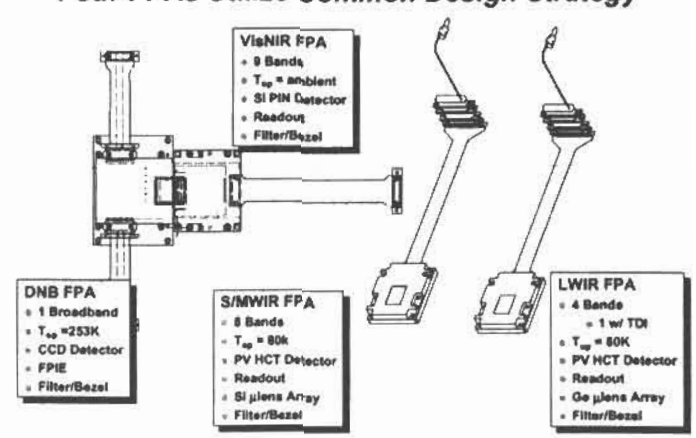
CCD Meets Signal to Noise Requirement Over Entire Dynamic Range Throughout Scan (I)



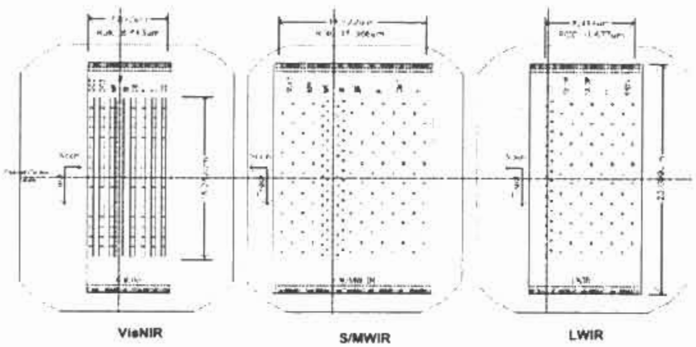
SNR Performance Exceeds Requirement Throughout Scan @ Lmin



Four FPAs Utilize Common Design Strategy

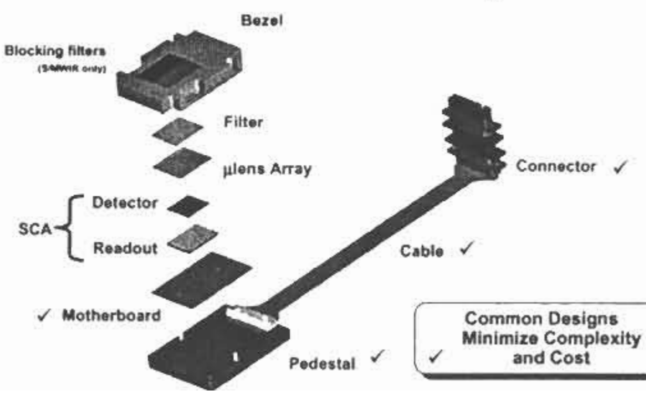


Band Layout for 3 Spectral FPAs



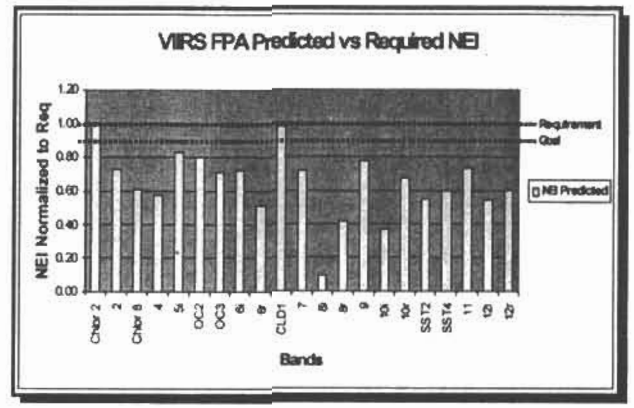
Low Detector Density Assures Negligible Optical Crosstalk

S/MWIR & LWIR FPA Components



✓ Common Designs Minimize Complexity and Cost

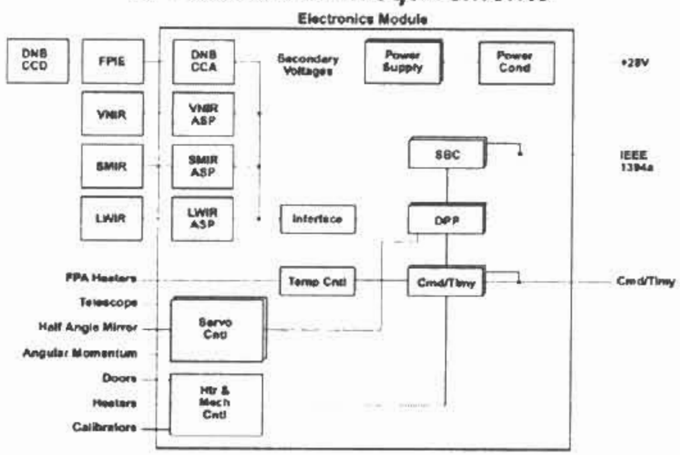
FPA Predicted NEI Better Than Goal



Typical Margin to FPA Specification is 35%

Electronics Module

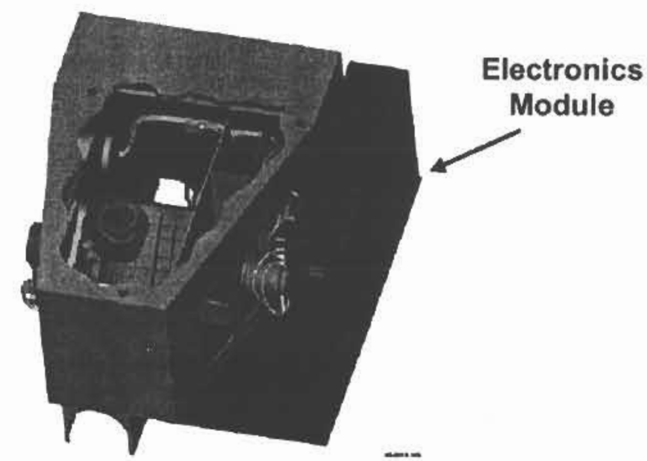
Electronics Module Meets or Exceeds All Requirements



Sensor Operation Controlled by Electronics Module

- Controls the Telescope and Half Angle Mirrors to Image the Desired Scene upon the Focal Plane Arrays
- Processes and Packetizes Science and Housekeeping Data into the CCSDS Format
- Communicates with the Spacecraft via IEEE 1394a (cable)
  - Commands and Telemetry
  - Science Data (High Rate and Low Rate Data)

Electronics Packaging Facilitates Integration and Testing



Electronics Module Requirements Documented in PS154640-114

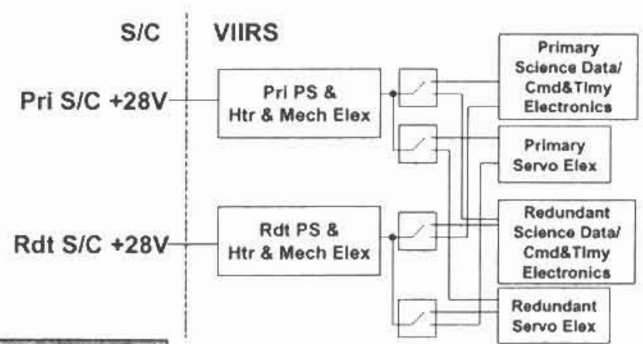
Rqmt. Number	Description	Units	Rqmt. Value	Tolerance	Predicted	Verification Method
ELM0184	Dimensions					
	Velocity	cm	25.4	Max	22.4	Test
	Nadir	cm	61.0	Max	61.0	Test
	Scan	cm	93.5	Max	93.5	Test
ELM0183	Mass	kg	49.7	Max	49.7	Inspection
ELM0242	Average Power[1]	W	170	Max	134	Test
ELM0034	Signal Accuracy	ENOB	11.6	Min	Comply	Test
ELM0254	HRD Average Rate[2]	Mbps	8.0	Max	6.7	Test
ELM0255	HRD Peak Rate	Mbps	10.5	Max	8.3	Test
ELM0256	LRD Rate	kbps	230	Max	79	Test
	Radiation[3]					
ELM0146	Total Ionizing Dose	krads (Si)	50	Min	Comply	Similarity
ELM0147.8	Single Event Effects	$MeV\text{-}cm^2/mg$	37	Min	Comply	Similarity
ELM0135	Operating Temperature	°C	-10 to +35	±3	Comply	Test

[1] Power is for Normal Operational Mode when VIIRS Acquires Science Data

[2] Orbital Average Data Rate Assumes 60% Day and 40% Night

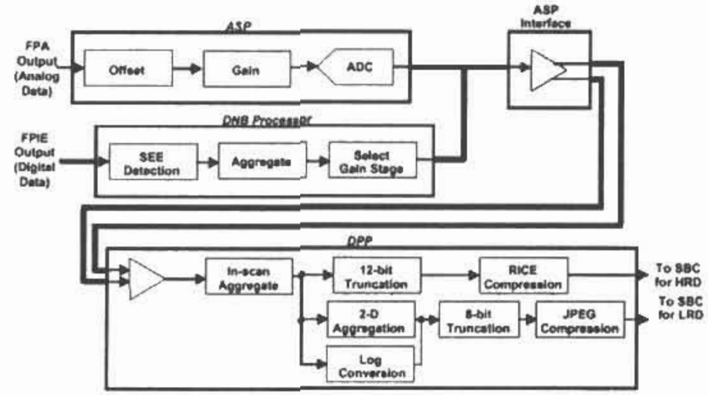
[3] Requirements Assume 100 mils Aluminum Shielding with 2x Margin

Cross-Strapping & Redundancy Designed to Exceed Sensor Life



Probability of Success
$P_{Success} = 0.91$
$P_{Rqmt} = 0.86$

Data Flows From FPAs and FPIE Through Electronics Module to SBC



HRD Rate Meets Peak and Average Data Rate Requirements

				Earth View Data			
				Day		Night	
	Acquired	Aggr/Trunc	Rice (CR=2.0)	# of Bands	Total Bits	# of Bands	Total Bits
DNB CCD (Samples x Pixels x Bits)	4055x16x16	4055x16x14	4055x16x14/2.0	1	454,160	1	454,160
Bits	1,038,080	908,320	454,160				
Radiometric Bands							
Single Gain (Samples x Pixels x Bits)	6298x16x14	3186x16x12	3186x16x12/2.0	8	2,446,848	7	2,140,992
Bits	1,410,752	611,712	305,856				
1.6r w/ 2:1 TDI (Samples x Pixels x Bits)	6298x32x14	3186x16x12	3186x16x12/2.0	1	305,856	1	305,856
Bits	2,821,504	611,712	305,856				
Dual Gain (Samples x Pixels x Bits)	6298x16x15	6298x16x13	6298x16x13/2.0	7	4,584,944	1	654,992
Bits	1,511,520	1,309,984	654,992				
Imaging Bands (Samples x Pixels x Bits)	12596x32x14	6398x32x12	6398x32x12/2.0	5	6,140,160	3	3,684,096
Bits	5,643,008	2,456,064	1,228,032				
			Subtotal		13,931,808		7,240,096

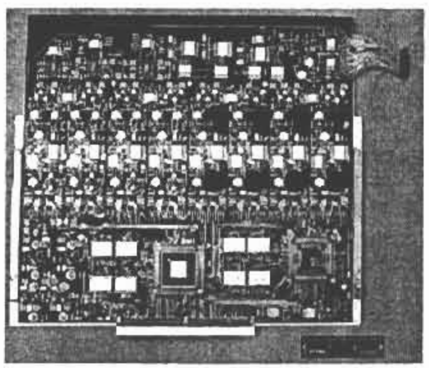
				Calibration Data			
				Day		Night	
	Acquired	Truncation	Rice (CR=2.0)	# of Bands	Total Bits	# of Bands	Total Bits
DNB CCD (Samples x Pixels x Bits x Views)	16x16x16x3	16x16x14x3	16x16x14x3/2.0	1	5,376	1	5,376
Bits	12,288	10,752	5,376				
Radiometric Bands							
Single Gain (Samples x Pixels x Bits x Views)	48x16x14x3	48x16x12x3	48x16x12x3/2.0	8	110,592	7	96,768
Bits	32,256	27,648	13,824				
1.6r w/ 2:1 TDI (Samples x Pixels x Bits x Views)	48x32x14x3	48x16x12x3	48x16x12x3/2.0	1	13,824	1	13,824
Bits	64,512	27,648	13,824				
Dual Gain (Samples x Pixels x Bits x Views)	48x16x15x2x3	48x16x13x3	48x16x13x3/2.0	7	104,832	1	14,976
Bits	69,120	29,952	14,976				
Imaging Bands (Samples x Pixels x Bits x Views)	96x32x14x3	96x32x12x3	96x32x12x3/2.0	5	276,480	3	165,888
Bits	129,024	110,592	55,296				
			Subtotal		511,104		296,832
			3% Overhead		433,297		226,108
		Earth + Cal + Overhead	Total (bits)		14,876,304		7,763,036
		Peak	Total (bps)		8,327,588	<10.5 Mbps	
Scan = 1.7864 seconds	60/40 Day/Night	Average	Total (bps)		6,734,792	<8.0 Mbps	

LRD Rate Requirement is Easily Met

	Earth View Data				
	Acquired	Aggr/Trunc	JPEG (CR=10)	# of Bands	Total Bits
DNB CCD (Samples x Pixels x Bits)	4055x16x16	4055x16x8	4055x16x8/10	1	
Bits	1,038,080	519,040	51,904		51,904
Imaging Bands (Samples x Pixels x Bits)	12596x32x14	3198x16x8	3198x16x8/10	2	
Bits	5,643,008	409,344	40,934		81,869
			Subtotal		133,773
	Calibration Data				
	Acquired	Avg & Trunc		# of Bands	Total Bits
DNB CCD (Samples x Pixels x Bits x Views)	16x16x16x3	16x12x3		1	
Bits	12,288	576			576
Imaging Bands (Samples x Pixels x Bits x Views)	96x32x14x3	32x12x3		2	
Bits	129,024	1,152			2,304
			Subtotal		2,880
			3% Overhead		4,100
	Earth + Cal + Overhead		Total (bits)		140,752
Scan = 1.7864 seconds			Total (bps)		78,791

Calculated Low Rate Data Well Under the Required 230 kbps

ASP Conditions and Digitizes Focal Plane Outputs



- Translates Focal Plane Clocks
- Supplies Biases to the Focal Plane
- Conditions the Focal Plane Outputs
- Digitizes the Outputs

Raytheon Demonstration Program ASP Circuit Card Assembly

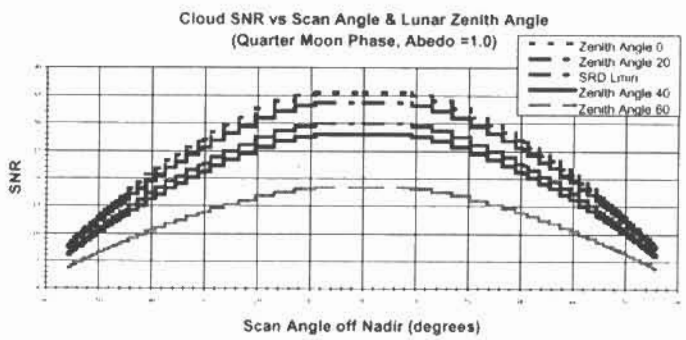
Challenging ASP Requirements Addressed by Demonstration Hardware

Rqmt. Number	Description	Units	Rqmt. Value	Tolerance	Predicted	Verification Method
ELM0058	ADC Data Accuracy	ENOB	12.3	Min	Comply	Test
ELM0031	Settling Accuracy	% of FS	0.01	Max	Comply	Test
ELM0038	Channel-to-Channel Crosstalk	% of FS	0.01	Max	Comply	Test
ELM0043	Gain Stability Over a Scan	% of FS	0.05	Max	Comply	Test
ELM0035	Amplifier Noise	μV RMS	100	Max	Comply	Test
ELM0029	Programmable Bias	Number	2	-	2	Design
ELM0030	Programmable Bias Resolution	% of FS	1	Min	0.7	Test
ELM0036	Programmable Update Rate	Scan	1	Min	1	Design
ELM0094	Self Test Function	-	-	-	Comply	Test

Daytime/Nighttime Band CCA Provides Single Event Effect Detection

- Provides Timing to the Focal Plane Interface Electronics (FPIE)
- Detects Single Event Effects on the High Gain Stages
- Selects the Gain Stage Based on Signal Level
- Passes Isolated Voltages to the FPIE and CCD

34 Different Aggregation Modes Provide 5% Variation in HRI



In-Scan Variable Aggregation & Truncation Reduces Data Rate

- Aggregation on Earth View Data Only
  - Single Gain Bands Only
- Truncation Performed after In-Scan Aggregation
  - Gain Bits (if Applicable) Retained & Upper 12 bits Retained
  - Resultant Data Meets 11.6 ENOB
- All Data Sent to LRD and to RICE sent after Aggregation & Truncation
- Aggregation Bypassed as a Unit in Diagnostic Mode
- Truncation may also be Bypassed as a Unit in Diagnostic Mode

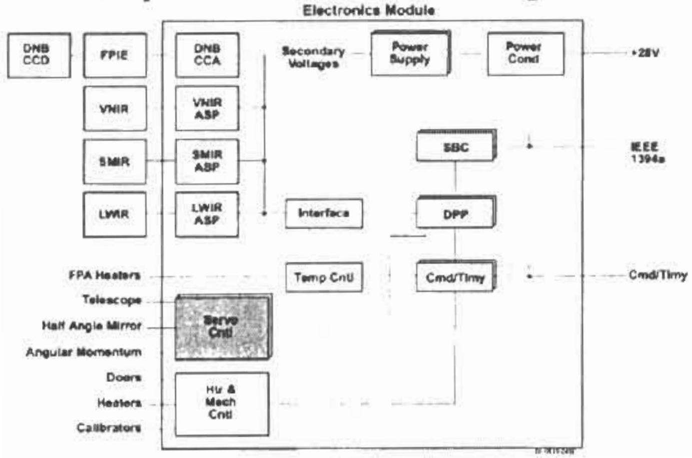
Command/Telemetry CCA Provides Hardware Control and Sensor Health & Status

- Provides Commands to Various Assemblies in the Electronics Module
  - Relay Pulse
  - Digital Pulse
  - Digital Level
- Reads Telemetry from throughout the Sensor
  - Analog Telemetry
    - Active
    - Passive (Thermistors)
  - Digital Telemetry

Single Board Computer (SBC) Controls Spacecraft Interface and Sensor Operation

- Communicates with the Spacecraft via 1394a (cable)
  - Commands
  - Telemetry Packets
  - Science Data Packets
    - High Rate Data
    - Low Rate Data
- Accommodates Uploads
  - Table Uploads
  - Software Patches and Revisions

Servo Controller Design Advanced by Raytheon Demonstration Program



Velocity Stability & Sensor Disturbances Requirements Allocated to Servo Controller

Rqmt. Number	Description	Units	Rqmt. Value	Tolerance	Predicted	Verification Method
ELM0070	Half Angle Mirror angular rate	Hz	0.27969	0.1% rms	0.054% rms[2]	Test
ELM0071	Position control for test	-	-	-	Comply	Test
ELM0072	Stow for safehold	-	-	-	Comply	Test
ELM0075	Telescope angular rate	Hz	0.55979	0.1% rms	0.026% rms[1]	Test
ELM0078	Launch pin interlock	-	-	-	Comply	Test
ELM0186	Uncompensated momentum	N-m-s	0.5	Maximum	0.02	Analysis
ELM0187	Uncompensated torque per axis	N-m	See Figure	Maximum	Comply[3]	Test

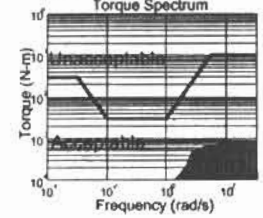
[1]Demonstrated rms error over 1 sec at constant rate

[2]Predicted (via simulation) rms error over 1 sec at constant rate

[3]See figure

Conditions for plot at right:
1) Motor cogging compensation is at least 90% effective
2) Transmitted torque reduction due to AMC not considered
3) Motors are at constant rate

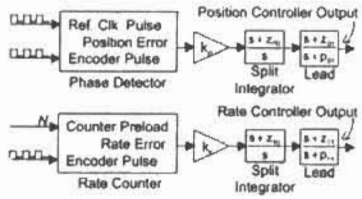
Telescope and HAM Transmitted Torque Spectrum



Telescope, HAM, and AMC Use SeaWiFS and MODIS Controllers

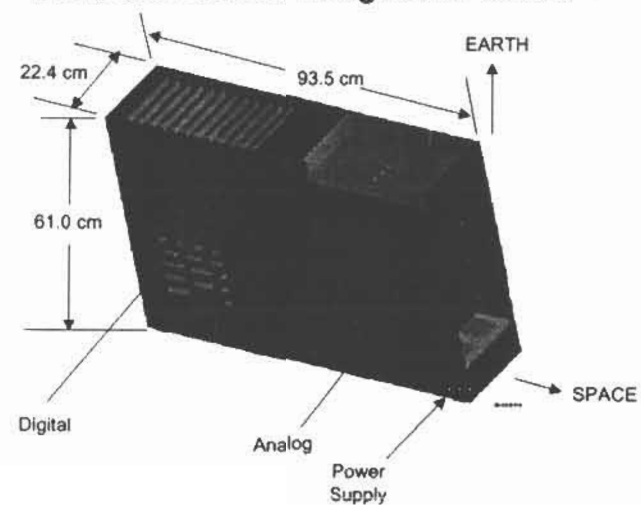
Controller Parameters	Units	Predicted			Requirement	
Position Loop		Tele	HAM	AMC	Value	Source
Phase margin	deg	45	45	45	> 35	Raytheon
Gain margin	dB	7	7	7	> 6	Engineering
Crossover	Hz	10	10	10	< N/4	Practice
Loop type at crossover	none	1	1	1	1 or 2	
Rate Regulator Loop						
Phase margin	deg	45	45	45	> 35	Raytheon
Gain margin	dB	7	7	7	> 6	Engineering
Crossover	Hz	40	40	40	N	Practice
Loop type at crossover	none	1	1	1	1 or 2	

N = application specific



- Proven SeaWiFS, MODIS and SBIRS Low Servo Designs Used to Reduce Risk and Cost
  - Constant Rate Reduces Applied Torque
- Telescope, HAM and AMC Servo Controllers Have the Same Structure
  - Facilitates Design, Integration and Test

Single Electronics Module Approach Reduces Sensor Integration Costs



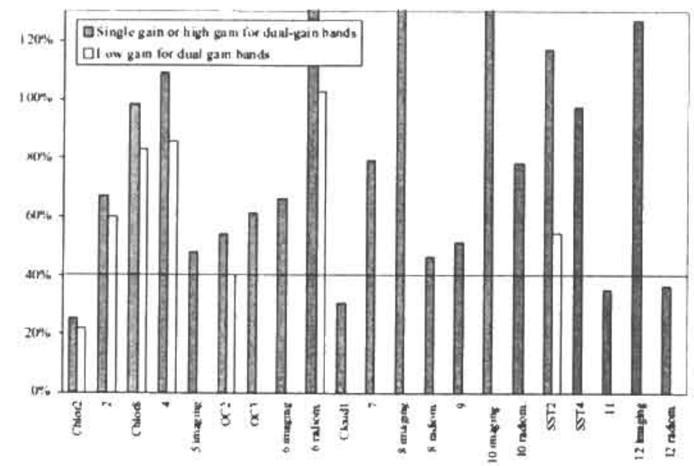
Radiometric Performance

Performance Summary for Low-gain State of Dual-gain Bands

Source File: F:VRPM014.xls
Q= watt m⁻² sr⁻¹ μm⁻¹

Band	λ (μm)	# in SH	Gain	Ltyp or Ttyp Q or K	Lmax or Tmax Q or K	Low gain for dual-gain bands: 1 x 3 aggregation SNR @ Ltyp (e-/e-)	1 x 3 aggregation NEdT @ Ttyp (K)	1 x 2 aggregation SNR @ Ltyp (e-/e-)	1 x 2 aggregation NEdT @ Ttyp (K)	1 x 1 aggregation SNR @ Ltyp (e-/e-)	1 x 1 aggregation NEdT @ Ttyp (K)	1 x 1 aggregation SNR Required (e-/e-)	1 x 1 aggregation NEdT Required (K)	SNR margin in Design
Chlor2	0.412	1	Dual	200.0	400.0	1780.5	n/a	1453.8	n/a	1028.9	n/a	841.0	n/a	22.2%
2	0.445	1	Dual	96.5	489.0	2496.6	n/a	2005.4	n/a	1418.6	n/a	886.0	n/a	60.0%
Chlor4	0.488	1	Dual	51.5	541.0	3050.1	n/a	2490.4	n/a	1761.0	n/a	961.0	n/a	82.8%
4	0.555	1	Dual	29.5	590.0	3775.3	n/a	2674.3	n/a	1891.0	n/a	1018.2	n/a	85.8%
OC2	0.672	1	Dual	22.0	490.0	3348.2	n/a	2732.4	n/a	1932.0	n/a	1379.0	n/a	40.1%
6 radiom.	0.865	1	Dual	25.0	270.0	3711.5	n/a	3032.1	n/a	2144.0	n/a	1058.0	n/a	102.8%
SST2	4.05	1	Dual	380	500	1034.5	0.035	844.7	0.048	597.1	0.068	388.3	0.105	54.8%

Most Bands Provide More Than 40% SNR Margin



Performance Summary for Single Gain or High Gain

Source File: F:VRPM014.xls
Q= watt m⁻² sr⁻¹ μm⁻¹

Band	λ (μm)	# in SH	Gain	Ltyp or Ttyp Q or K	Lmax or Tmax Q or K	High gain summary: 1 x 3 aggregation SNR @ Ltyp (e-/e-)	1 x 3 aggregation NEdT @ Ttyp (K)	1 x 2 aggregation SNR @ Ltyp (e-/e-)	1 x 2 aggregation NEdT @ Ttyp (K)	1 x 1 aggregation SNR @ Ltyp (e-/e-)	1 x 1 aggregation NEdT @ Ttyp (K)	1 x 1 aggregation SNR Required (e-/e-)	1 x 1 aggregation NEdT Required (K)	SNR margin in Design
Chlor2	0.412	1	Dual	44.9	130.0	763.9	n/a	623.7	n/a	441.0	n/a	352.5	n/a	25.3%
2	0.445	1	Dual	40.0	127.0	976.6	n/a	797.4	n/a	563.9	n/a	337.8	n/a	66.9%
Chlor4	0.488	1	Dual	32.0	107.0	1067.1	n/a	871.3	n/a	616.1	n/a	310.6	n/a	98.7%
4	0.555	1	Dual	21.0	78.0	911.8	n/a	780.8	n/a	530.0	n/a	257.1	n/a	108.3%
5 imaging	0.645	1	Single	22.0	400.0	335.2	n/a	273.7	n/a	193.5	n/a	130.7	n/a	48.1%
OC2	0.672	1	Dual	10.0	50.0	645.3	n/a	526.8	n/a	372.6	n/a	242.1	n/a	53.9%
OC3	0.751	1	Single	9.6	61.0	557.0	n/a	454.8	n/a	321.6	n/a	199.1	n/a	61.5%
6 imaging	0.865	1	Single	25.0	278.0	435.2	n/a	355.4	n/a	251.3	n/a	151.2	n/a	66.2%
6 radiom.	0.865	1	Dual	6.4	25.0	864.1	n/a	705.5	n/a	498.9	n/a	215.3	n/a	131.7%
Cloud1	1.24	1	Single	5.4	95.0	228.4	n/a	186.5	n/a	131.9	n/a	101.0	n/a	30.6%
7	1.378	1	Single	6.0	41.0	256.5	n/a	209.4	n/a	148.1	n/a	82.7	n/a	79.0%
8 imaging	1.61	1	Single	7.3	90.0	146.7	n/a	121.4	n/a	85.9	n/a	6.0	n/a	1336.1%
8 radiom.	1.61	1	Single	7.3	72.5	460.5	n/a	367.5	n/a	300.3	n/a	342.2	n/a	46.2%
9	2.25	1	Single	0.12	5.6	26.2	n/a	21.4	n/a	15.1	n/a	10.0	n/a	51.2%
10 imaging	3.74	1	Single	270	310	45.4	0.408	37.0	0.500	26.6	0.707	7.6	2.500	[illegible]
10 radiom.	3.7	1	Single	270	310	148.1	0.129	119.3	0.157	84.3	0.222	47.3	0.396	78.2%
SST2	4.05	1	Dual	300	343	893.6	0.024	729.6	0.034	515.9	0.048	237.2	0.107	117.8%
SST4	8.55	1	Single	270	340	1621.7	0.027	1324.0	0.033	936.1	0.046	475.5	0.091	97.0%
11	10.7625	1	Single	300	400	2253.4	[illegible]	1823.6	0.036	1289.5	0.052	960.6	0.070	36.7%
12 imaging	11.45	1	Single	210	310	81.7	0.362	74.8	0.466	52.9	0.661	23.3	1.500	126.9%
12 radiom.	12.0125	2	Single	300	340	2428.9	[illegible]	1982.5	0.037	1401.9	0.053	1024.4	0.072	36.9%
DNB	0.7		Variable	6.70E-05	500	30.0	n/a			9.5	n/a	6.0	n/a	10% - 400%

The radiance listed for the DNB is the minimum scene radiance.

All Bands Meet Band-to-Band Registration Requirements

Band-to-band Registration (worst case)

ERROR SOURCE	Value	Units	BAND-TO-BAND MISREGISTRATION (PIXELS)			
			Radiometric Bands		Imaging Bands	
			Within FPA	FPA to FPA	Within FPA	FPA to FPA
Dynamic Effects						
Scan Velocity Errors	0.0015	Frac	0.076	0.076	0.018	0.018
Telescope Focal Length Error	0.0015	Frac	0.057	0.057	0.0135	0.0135
Elec Timing Jitter	8.0E-09	Sec	9.06E-05	9.06E-05	1.81E-04	1.81E-04
Static Effects						
Field Stop Misalignment	2	µm	0.0076	0.0076	0.015	0.015
Beam Splitter/Aft Optics Misalignment	12	µm	N/A	0.012	N/A	0.024
Timing Adjustment Granularity	1.1E-07	Sec	N/A	0.0012	N/A	0.0012
FPA misalignment	10	µm	N/A	0.028	N/A	0.075
Differences In Telescope Distortion	Variable		0.11	0.159	0.038	0.066
TOTALS (Percent Pixel Area Misregistration)		HSR Frac	0.23	0.33	0.08	0.19
SPECIFICATION (Max Misregistration)		HSR Frac	0.36	0.36	0.20	0.36
MARGIN		%	36	8	58	47

Refinement of aft telescope design or FPA layout can further reduce telescope distortion component of BBR

Summary: Band-to-Band Registration and LOS Pointing Knowledge Excellent

- Raytheon Sensor provides Band-to-Band Registration performance with margin, without resampling
- Meets new Line of Sight Pointing Knowledge requirement with margin
- Combined with Spacecraft pointing performance as specified in SRD, Raytheon Sensor provides excellent Mapping Uncertainty performance
- Meets Threshold Mapping Uncertainty requirements of all EDRs
  - Meets Objective Mapping Uncertainty levels of most EDRs, approaches Objective on remainder
  - Circular Error at nadir 123 meters
    - Realistic Spacecraft and Sensor improvements would provide performance approaching original Earth Location specification of 67 meters

Our Algorithm PDR Design and Software Is Adapted/Adopted from Heritage Algorithms

- Heritage Designs Include: MODIS, AVHRR, OLS, and SeaWifs
- The Research software Implements the ATBDs for EDRs, SDRs (gelocation and calibration), and Intermediate Products
- Our design includes the linkages between intermediate products (e.g cloud mask) and the EDRs
- Our software follows procedures outlined in Raytheon's software development process (e.g. "spiral development" Model, CMM level-2)

Obtained a "Peer-reviewed" Sound Theoretical Basis For Every EDR

- Considered all reasonable alternatives in trade space
- Ruled out candidates with "unreasonable" requirements on sensor or external data
- Adopted, adapted, or developed baseline approach, driving development risks to low
  - Focused on maximum reuse of recent technology, with development and refinement where needed
  - Used MODIS/other teams' efforts as algorithm development and design starting points
  - Peer-reviewed ATBDs across three iterations
  - ATBD review process internal to Raytheon with use of outside consultants followed EOS approach

Algorithm Development Status (1 of 3) and Delivery of the V3 ATBDs

EDR	Final Baseline	Adopted/Adapted/Developed	ATBD#
Imagery	Tie point/interpolation	Adapted ([illegible])	[illegible]
SST	4-Channel Skin—ATSR, MODIS Air-mass classification Cirrus, aerosol mitigation	Adapted ([illegible], Brown, Emery)	[illegible]
Soil Moisture	CMIS/VIIRS Data Fusion	Adapted (Carlson)	Y2387
Aerosol Optical Thickness, Particle Size, Effective Radius	Dark Pixel Method	Adapted (Kaufman, Tanre, Vermote) Developed radius (Vermote)	Y2388
Suspended Matter	Multiple Indices & Dominant Type	Adapted (GOES, SeaWiFS, AVHRR)	[illegible]
Cloud Base Height	Cloud Property LUT	Adapted (Hutchison, Wilheit)	Y2391
Cloud Cover/Layers	Statistical/Properties	Adopted/Extended (AFWA)	Y2392
Cloud Effective Particle Size, Optical Thickness	UCLA Ice & Water	Adopted (Ou, Liou)	Y2393
Cloud Top Height, Temp., Pressure	UCLA Ice & Water IR	Adopted (Ou, Liou)	Y2396

Algorithm Development Status (2 of 3)

EDR/SDR	Final Baseline	Adopted/Adapted/Developed	ATBD#
Albedo, Surface	Baseline: nonlinear regression (neural net) Alternate: simplified MISR	Adopted (Liang, Martonchik, Pinty, Verstraete) Adapted (MRPV, CALMIRA/Van)	Y2398
Land Sfc. Temp	4-Channel Land Cover	Adapted	Y2399
NDVI	NDVI, EVI (VVI)	Adopted (Tarpley, Running, Huete)	Y2400
Snow Cover/Depth	MODIS threshold and Spectral Mixture	Adopted (Hall, Dozier)	Y2401
Surface Type	Automated Decision Tree	Adapted (Townshend, DeFries)	Y2402
Ocean Current	Maximum Cross Correlation	Adopted (Emery)	Y2403
Fresh Water Ice	Tie Point	Adopted (Massimo and Comiso)	2404
Ice Surface Temp.	Split Window	Adopted	Y2405
Littoral Sed. Tran.	Bathymetry	Developed (Lee, Carder, Vasilkov)	Y2406

Algorithm Development Status (3 of 3)

EDR	Final Baseline	Adopted/Adapted/Developed	ATBD#
Net Heat Flux	Regression/Neural/Bulk	Adapted (Ruprecht, Liu)	Y2407
OC/Chlorophyll	Carder/MODIS Case 2 Regionally tuneable	Adapted (Carder)	Y2408
Ocean Atmos. Corr.	Improved SeaWiFS With full residual polarization handling	Adapted (Gordon, Wang, Liu)	Y2411 (IP)
Sea Ice Age/Edge Motion	MCC/Threshold/Filtering and Segmentation/Energy Balance	Adapted (Emery, Tsatsoulis, Yu, and Rothrock)	Y2409
Mass Loading	Physical Retrieval	Adapted (Vasilkov)	Y2410
Land Atmos. Corr.	Radiative Transfer LUT MODIS	Adopted (Vermote)	Y2411 (IP)
Cloud Mask	Thresholding/Phase	Adapted (MODIS/CLAVR, Stowe)	Y2412
Precipitable Water	Five-band TIR	Adapted (Huang, Mensel)	Y3251
Fire Product	Raytheon HSS/MODIS	Adapted (Raytheon HSS, Flynn)	Y3252
Geolocation	MODIS/ETM	Adopted (Wolfe, Storey)	Y3258

Algorithm Requirements Accomplished

- Algorithm Theoretical Basis Documents (ATBDs) completed and delivered at PDR (SRD 3.2.1.1) for all EDR's, SDRs, intermediate products and applications.
- Research Software that implements each of the EDRs completed, demonstrated and delivered at PDR.
- Algorithm Architecture, RDRs, SDRs, and External Interfaces defined to Module level and below for all EDRs (SRD 3.2.1.2)
- Processing pipeline identified for each EDR module (SRD 3.2.1.5)
  - Demonstrated Pipelines to show low risk to fit the 20 minute timeline
- System and Algorithm Subsystem Specifications established with Stratification per SRDX4.3.3-3 based on current SRD 3.2.1.1
- Error Budgets identified for each EDR, including ancillary/auxiliary and sensor data inputs per SRDX4.3.3-2 and 4.3.4-1
- EDR verification across stratification per SRDX4.3.3-1 based on assumed sensor performance shows VIIRS can meet requirements

Excellence: Low-Risk Near-Objective EDRs

- "Near Objective" Imagery, SST & >Half Category II EDRs
- Subjective Weighted Average EDR Attribute Performance